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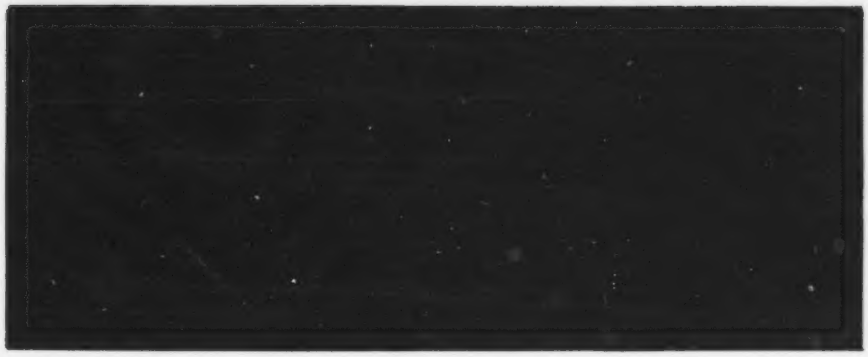

V-86-07-0028

DEVELOPMENT TOWARDS MORE EFFICIENT OPERATION OF AN ALFALFA DEHY PROCESSING SYSTEM

- Alfalfa Dryer Feed Delivery Automation -

V-86-07-0028

by

Brad Hill

SASKATCHEWAN DEHYDRATORS ASSOCIATION

March 1988

91-01726/

SASKATCHEWAN DEHYDRATORS ASSOCIATION

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March 21, 1988

Ms. Connie Lambert
Saskatchewan Agriculture
Walter Scott Bldg.
3085 Alberta Street
Regina, Saskatchewan
S4S 0B1

Dear Ms. Lambert:

The attachments herein constitute a final technical report for projects V-86-07-0028 and 0029. I have also included a statement of expenditures for the projects.

I apologize for the delay in submitting the reports. I trust that the information is complete and satisfactory so that it will action the final payment.

Thank you very much for your support and co-operation in the projects.

Sincerely

D.A. Pulkinen

D. A. Pulkinen
Director of Research

DAP/jc

enclosures

FEEDER - I & II (V-86-07-0028)

Date: 18-Mar-88
Reporting Date: 29-Feb-88

	Budget			Actual		
	Jun/86-Mar/87	Apr/87-Mar/88	TOTAL	Jun/86-Mar/87	Apr/87-to date	TOTAL
Salaries & Benefits						
Dale Pulkinen	3,578	2,300	5,878	805	1,018	1,823
Brad Hill	11,822	1,450	13,272	12,824	15,574	28,398
Sub-total	15,400	3,750	19,150	13,629	16,592	30,221
Lab Tech	1,650	1,400	3,050	948	3,726	4,674
Gen labour	1,200	750	1,950	374	3,212	3,586
	18,250	5,900	24,150	14,951	23,530	38,481
Equipment						
Transport & modify feeder	16,000		16,000	4,517		4,517
Feed control system	5,000	1,000	6,000	6,117	2,381	8,498
Monitoring eqpt	300		300	340	264	604
	21,300	1,000	22,300	10,974	2,645	13,619
Materials & Supplies						
Shop supplies, hdwe, etc.	400	500	900	146	341	487
Drafting supplies	200		200	150	(150)	0
Computer software	500	500	1,000	209	(141)	68
Lab supplies & misc	600	200	800	32		32
In-House analysis (@ cost)	1,800	600	2,400	471	387	858
Freight	500	100	600	256	25	281
L.D. Telephone	300	100	400	264	199	463
Sub-total	4,300	2,000	6,300	1,527	661	2,188
Travel						
In-house	600	600	1,200	76	525	601
Mileage & other	1,050	400	1,450	283	439	722
	1,650	1,000	2,650	359	964	1,323
Workshops/seminars						
Direct expenses	500	500	1,000	0		0
Overhead & Administration						
30% of labour	5,475	1,770	7,245	4,485	7,059	11,544
Other						
Sub-Contracts	9,000	0	9,000	1,594	1,220	2,814
Dismantle	0	2,500	2,500	0		0
	9,000	2,500	11,500	1,594	1,220	2,814
TOTAL	60,475	12,170	72,645	33,890	36,079	69,969

ACKNOWLEDGEMENTS

This project was supported in part by Industrial and Regional Development Program - Regional Industrial Expansion and by Agricultural Development Fund - Saskatchewan Agriculture. Their support is gratefully appreciated.

Summary

Work to improve the wet chop feed delivery was initiated during the summer of 1986 and continued into the summer of 1987. An experimental belt scale was built to monitor the chop mass flow to the dryer from two experimental feeders. These feeders were built to smooth the flow of chop in order to improve the accuracy of the scale. The final step to wet chop mass flow automation was the integration of the feed flow measurement with a computer and feedback to the feeder drive system.

The final feeder design greatly improved the feed delivery uniformity. Primary feed disturbances or feed surges associated with the conventional feeder design were virtually eliminated. The feed control system, when implemented with the redesigned feeder, responded quicker and more accurately to variations in mass flow than with the conventional feeder. The feed control system was able to maintain a relatively constant mass flow rate for all tests performed; with the most success from the feed delivered by the final design consisting of a conventional slat feeder covered with a continuous rubber belt.

The effect that the improved feed delivery had on the dryer operation was not evaluated; as the 1987 production season expired prior to the initiation of the tests. It is evident from the test results that the implementation of the feed control system will change the control responsibilities of the present temperature control system. Retuning of the present temperature control system is required to ensure stability in the process and ensure proper evaluation of feed automation.

Completion of this project requires additional time and equipment. Additional electronic scale equipment is required to ensure consistent mass flow rate measurement necessary for a fully automatic control system. Full production time trials are required to test the final feeder design for operational feasibility and to determine the economic benefits of the feed control system.

INTRODUCTION

The objective of this project was to improve dry chop moisture content uniformity and optimize drying efficiency through better control of the wet chop mass flow. By maintaining uniformity in the input parameters the final output of moisture content should be maintained more consistently. Optimization of the drying efficiency will result in reduced dehydration costs.

Previous work by the U of S and the Alfalfa Research Lab has shown that significant variations in the feed flow impede dryer optimization. Fluctuations in the mass flow cause constant variations in the moisture content of the final product and frequent changes in the required natural gas energy input for drying.

The present, or conventional feed delivery system, consists of an inclined bed on which two drag chains and numerous slats convey the chop past a levelling device; which is then discharged by a flail or picker to a belt conveyor. This conveyor delivers the chop into a rotary drum dryer. The system is designed to deliver a relatively constant volume (figure 1). The mass flow from this system, however, is very erratic; with basically two types of flow disturbances. They will be referred to as primary and secondary disturbances.

Primary disturbances are intermittent and frequent surges of hay which show up as spikes in the chop mass flow. These are caused by the slats as they round the head pulley and dump accumulated chop. On average 15-20% of the signals recorded were greater than + or - 30% the average flow (figure 2), and many of the spikes were 50-70% above the average load. A measurement device would require significant damping to smooth this variation in the flow. The result would be a much slower control response and less effective control. The elimination of these types of disturbances is the objective of re-designing the feed delivery system.

The secondary disturbances are longer term variations in the average chop mass flow. These flow variations are primarily due to the inconsistencies in the wet chop density caused by compaction of the chop by the gravity feeder and the front end loads that feed the delivery system. The resulting mass flow rate will vary as much as 50% over a 5-15 minute period of time. Our objective was to eliminate these types of fluctuations by the proposed feed control system.

RESULTS

Phase I: Improve Feed Flow Uniformity

A: Re-designed Feed Delivery System

The feeding system was re-designed in 1986, installed and tested at Carlea Alfalfa Processors. Further testing in 1987 led to further re-design due to operational problems. Consequently, two feeder designs were built and compared to the conventional feeder for uniformity of feed delivery and functional feasibility. Both designs utilized the concept of a smooth belt surface which would presumably discharge the hay evenly to the dryer.

Design 1: Belt Conveyor Design

The first design replaced the slats and chain conveying system on the feeder with a single conveyor belt (figure 3). The design showed some significant improvements in feed flow uniformity but had some operational problems. The surging associated with the conventional feeder was reduced by the belt but not eliminated. The number and magnitude of the surges was reduced to approximately 20% of the number of conventional feeder spikes. The flow was much smoother resulting in more consistent scale measurements, and reduced spillage from the belt(Figure 4).

The feed surging was not eliminated however. Feed surges originated from the modifications required for the belt installation. Angled skirts on each inside wall of the feeder were installed to keep the edges and underside of the belt clean. Approximately 4 inches of both ends of the picker had to be removed to clear the skirting. The result was intermittent feed surges; as the hay would by-pass the picker.

The belt transmission system was not adequate from an operational standpoint. The belt had to be constantly monitored for tracking and traction slip. The belt would slowly track back and forth depending on the hay load distribution. The belt also would slip if overloaded, causing unstable and unacceptable operation.

One observation to note was difference in secondary feed disturbances associated with the loader fed feeder compared to the apron fed feeder. Load fluctuations were more frequent when fed by the loader directly.

The mass flow rate of both feeders varied by as much as 50% over a 5-20 minute period (figure 5). Due to the frequency of the fluctuations coinciding with the loading of the feeder and the relatively short period of the fluctuations, it was concluded that the mass flow variations were due to density variations of the chop. Chop density will vary due to compaction within the feeder itself and in the front-end loader bucket that feeds the

system. Wetter chop, which compacted more readily, appeared to accentuate these density variations.

Design 2:Combined Slat and Belt Feeder

The second design was a combined belt and conventional feeder; which gave the benefit of a smooth conveying surface combined with the strength and reliability of the slats and chains (Figure 6). Also, it was a very simple adaption. The belt was laid over top of the slats and spliced continuous. It was not attached to the slats and was relatively loose. The weight of the belt itself maintained it in position, and it travelled at the same speed as the slats. Flexible rubber belting was attached to the sides of the main belts and lapped over the chains in order to keep the hay out from under the slats. A new undercarriage was installed to facilitate the installation of belt, and the picker was extended to pick the hay clean to within 1/2" of the belt's surface.

The resulting feed flow was by far the most uniform. Surges had all but been eliminated as indicated by the stable scale reading. This feeder was operated only at the end of the season for about 24 hours. The temporary splice, used to get the feeder operational, failed. Time limitations did not allow us to fine-tune and adequately test this feed delivery system.

B. Mass Flow Monitoring

The first priority of the project was to develop a method to monitor the mass flow accurately and consistently. The mass flow measurements could then be used to compare the uniformity of the various delivery designs. The experimental scale was adapted to the dryer delivery belt conveyor that was operating at the Carlea site. The scale basically consisted of the belt conveyor, an electronic load cell, a signal conditioner and a computer display read out.

The conveyor pivoted freely at the furnace end and suspended in the middle where the load was measured. The weight of the conveyor was counter-balanced by a weighted lever system, and the weight of the hay was multiplied to allow for full use of the load cell's measurement range.(Figure 7) The product weight on the belt (live weight) is in the order of 30-50 lbs. The belt travels at 400 fpm.

Converting the existing belt was convenient; however use of the conveyor caused operational problems. The major problem experienced with the scale was associated with ongoing and relatively large load changes measured by the scale. There was an accumulation of mass flow as indicated by the scale readings, even though there was no change in the drying load. This was identified to be dead weight drift or inconsistency in the conveyor's counter-balanced weight.

The conveyor weight, or dead-weight variations were attributed to hay accumulation on the conveyor. For the periods tested, the dead weight increased only after the conveyor had been cleaned, allowing the hay to re-accumulate (figure 8). Surges from the feeder caused hay spillage onto the conveyor framework. Further, the shallow belt troughing and the high belt speed added to the spillage problem over the edge of the belt. Spillage could be reduced by reducing belt speed, by increasing the trough of the belt, and by delivering a uniform flow of feed to the conveyor. The majority of the tests had no drift in the dead weight: as the hay accumulated to a point and then seemed to stabilize.

Climatic conditions also caused some load fluctuations. Wind gusts could cause fluctuations in the measured load by as much as 4 lbs. or 10% of the load factor. It seems feasible that this load disturbance could be eliminated by enclosing the conveyor inside a wind shield.

Redesign of the feed delivery system and filtration of the noise in the load signal reduced the fluctuations in feed flow to + or - 1lb (Figure 9). This relates to + or - 2% - 4% of the load range: which is acceptable for the application of a feed control system.

Phase II Results And Analysis

Feed Control Operation From Each Of The Feeders

The control function used is fairly simple. The actual load recorded by the scale is compared to a desired load. The difference in the two initiates a change in the output, which in this case, is the feeder delivery speed. Once the scale is functioning consistently, the computer manipulates the feeder's delivery speed in order to maintain a constant mass flow (figure 10). The satisfactory operation of this control system depends on the uniformity of the feed flow.

The consistency of the signal input dictates the response time of the control system and the stability of the output. An erratic signal requires more damping. This is accomplished by averaging more control input values, or by using a mechanical damper in the scale mechanism. The result is a slower response time and an increased settling time.

The system was initially set to average five scale measurements before initiating a control response. The controller update time was approximately six seconds, which placed the settling time at about 30 seconds. The settling time is the time required to reach steady state, and is estimated to be approximately 5 times the update time. Once the feed flow was

more uniform, the averaging value was dropped to three seconds. This increased the update time to about 4 seconds and the settling time to 20 seconds.

The feed controller operated at varying degrees of success from the chop delivered from each of the feeders. The erratic feed associated with the conventional and, to a lesser degree, the first redesigned feeder caused large fluctuations in the drag speed demanded. This resulted in large fluctuations remaining in the feed flow. This is a good example of feed surges limiting the effectiveness of the control system (figure 11).

The feed control from the second feeder design improved the feed control action by delivering uniform flow of chop, allowing the control system to respond to actual mass flow fluctuations such as those associated with density variations. Surges were all but eliminated. This allowed the control output to be smooth, resulting in a constant mass flow of chop (Figure 12).

The temperature control system was expected to stabilize once the feed flow was stabilized. This, however, did not happen. Tests showed that the controller output is virtually unstable (Figure 13). Because of the frequent disturbances previously experienced in the wet chop mass flow, the control system demanded quick response. This, combined with improper control output to heat requirement calibration , makes the process virtually unstable. The result is constant oscillation of the control output,(gas valve position); as the controller continually overshoots.

The only short term variable that the temperature control system was compensating for was the variation in wet chop mass flow. Improved control of the wet chop mass flow will require a less responsive temperature control function. Therefore, the feed control system requires the retuning of the temperature controller and proper calibration of the controller output in order to allow for proper evaluation of the controller under stable dryer operation.

Conclusions

There are a number of conclusions that can be drawn from the results: which bring us closer to a feed control system and ultimately improved dryer control. However a number of questions remain unanswered.

The final feeder design combining the belt and slats proved to deliver the most uniform flow of chop. The use of the flat belt proved to be necessary to eliminate the surging caused by the slat conveyor. This improved flow aided in the performance of the feed control system by allowing it to be responsive to significant changes in mass flow only.

The control system was able to maintain a constant mass flow of feed to the dryer. The response time of the controller can be very fast and precise if the feed flow is smooth enough to keep the dampening to a minimum.

The existing temperature control system is tuned for quick response to sudden and large variations in feed flow. This causes instability under certain hay conditions: presumably very wet and very dry conditions. Once the feed control system is operational, the temperature control system can be re-tuned to stabilize the drying process.

The question remains as to what extent this control will improve the product quality and optimize drying capacity. Due to the late testing of the final feeder design, tests on the effect it may have on drying efficiency were not performed.

The reliability and consistency of the scale under various operating conditions remains a question. The scale accurately senses changes in feed flow; however dead weight variation remains a problem. Contacts and discussions with a scale manufacturer indicate that this problem has been addressed under other applications, which may be transferable to our environment.

Additional time is required to evaluate the long term feasibility of the new feeder design and of operating the feed control system in parallel to the existing temperature control system. Additional testing is required to determine the economic benefits of a feed control system.

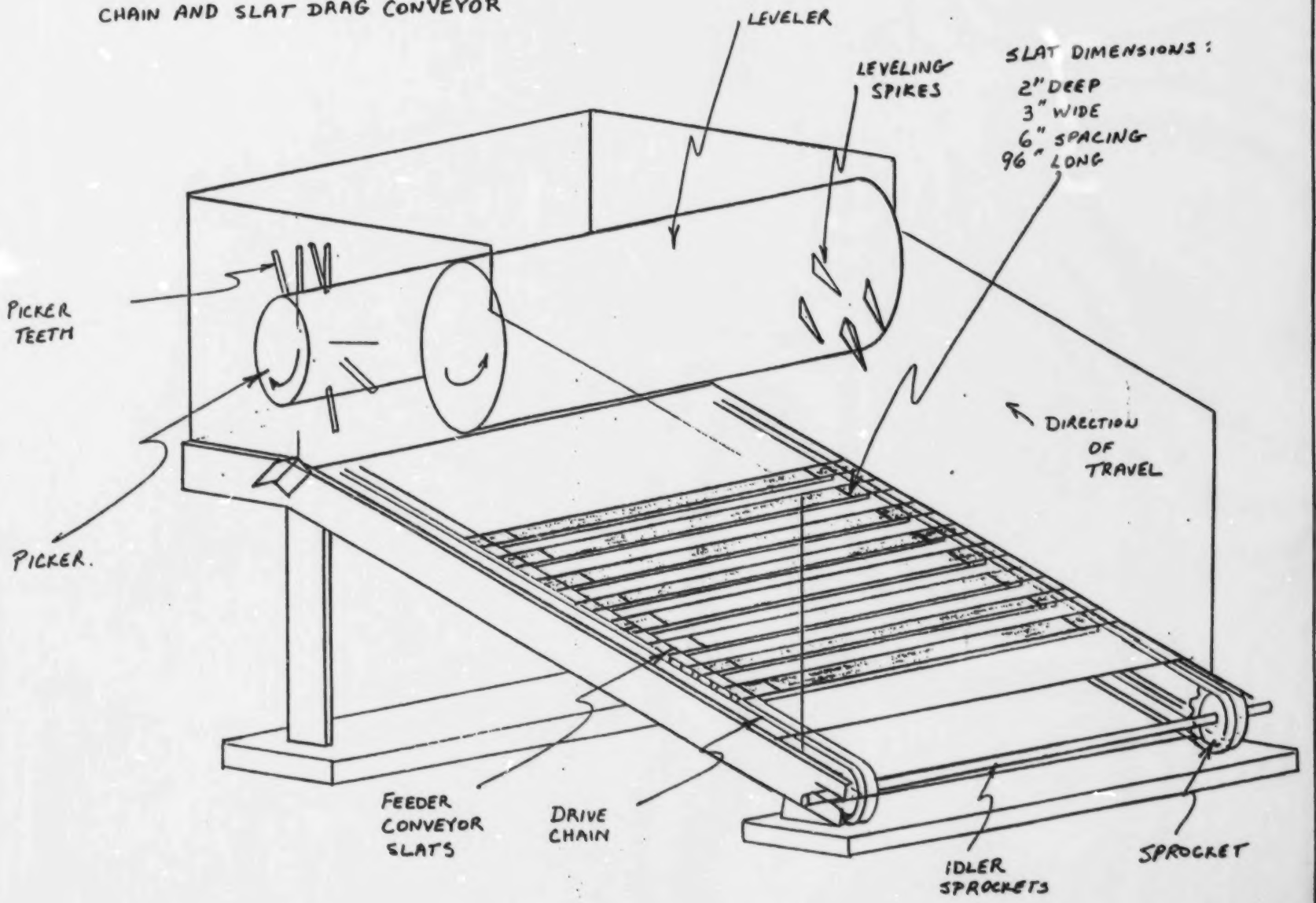
Future Work

Future development consists of implementing the findings of this report, including the adoption of the final feeder design along with the installation of commercial scale equipment to ensure operational reliability. Further work is required to stabilize the existing temperature controller on the dryer. Once this has been accomplished, improved feed control can be fully evaluated.

FIGURE 1: FEEDER CUT AWAY VIEW

CONVENTIONAL FEEDER

CHAIN AND SLAT DRAG CONVEYOR



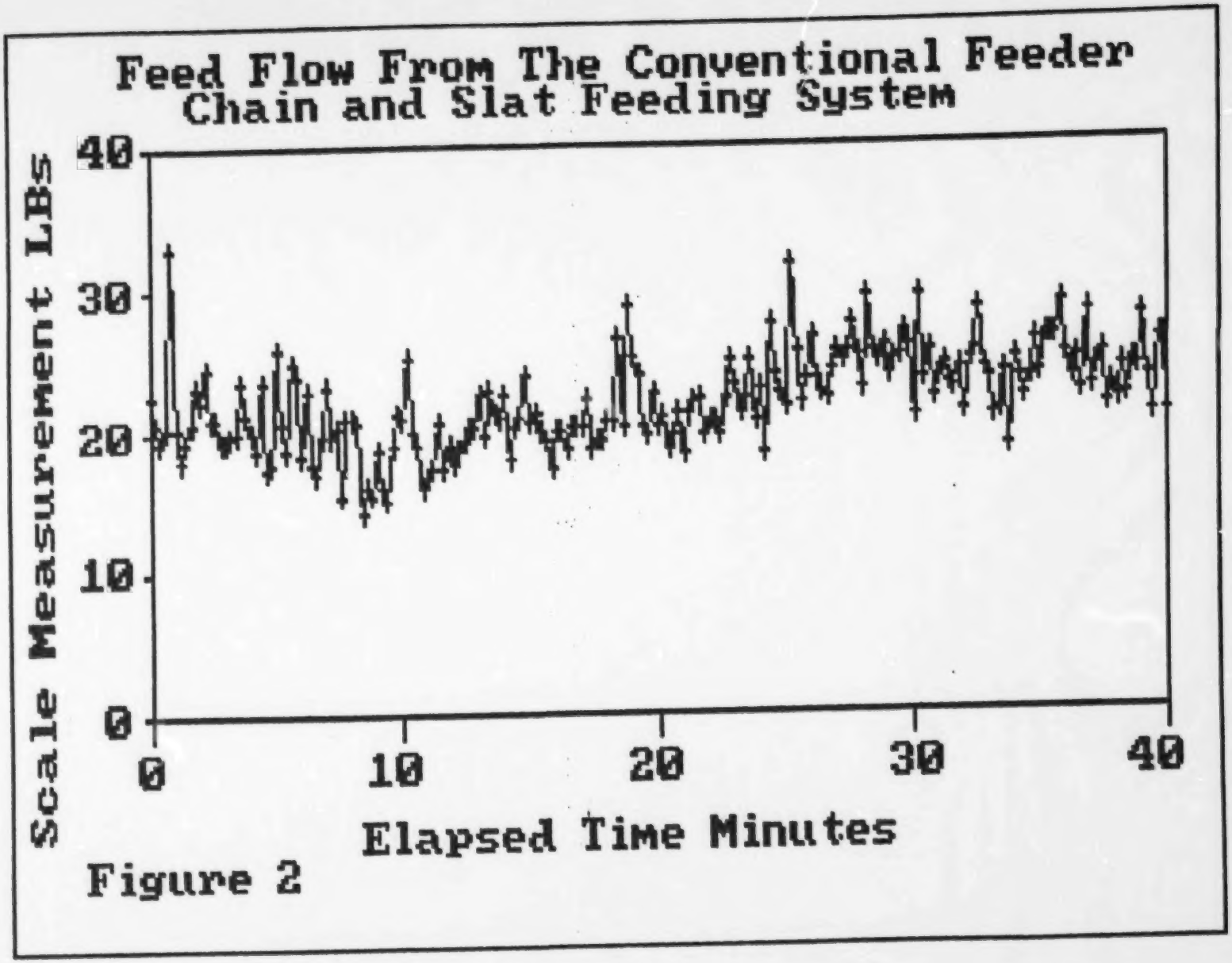

Feed Flow From The Conventional Feeder
Chain and Slat Feeding System
Scale Measurement LBs
40
30
20
10
0
0
10
20
30
40
Elapsed Time Minutes

Figure 2

FIGURE 3: FEEDER CUTAWAY VIEW

MODIFIED FEEDER - DESIGN NO. 1

BELT SURFACE CONVEYOR

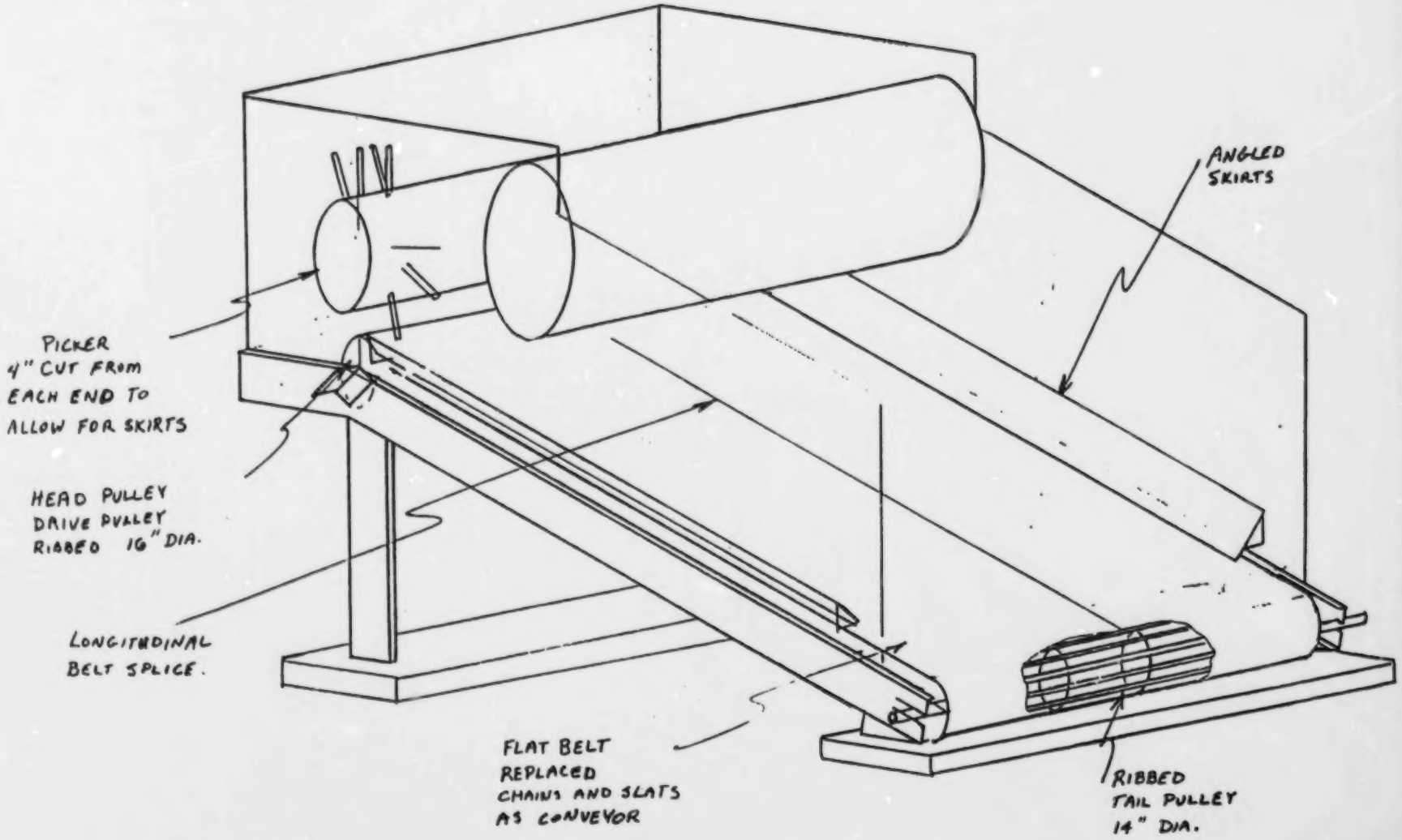

ANGLED SKIRTS
PICKER 4" CUT FROM EACH END TO ALLOW FOR SKIRTS
HEAD PULLEY DRIVE PULLEY RIBBED 16" DIA.
LONGITUDINAL BELT SPLICE.
FLAT BELT REPLACED CHAINS AND SLATS AS CONVEYOR
RIBBED TAIL PULLEY 14" DIA.

Figure 4 Feed Flow Uniformity

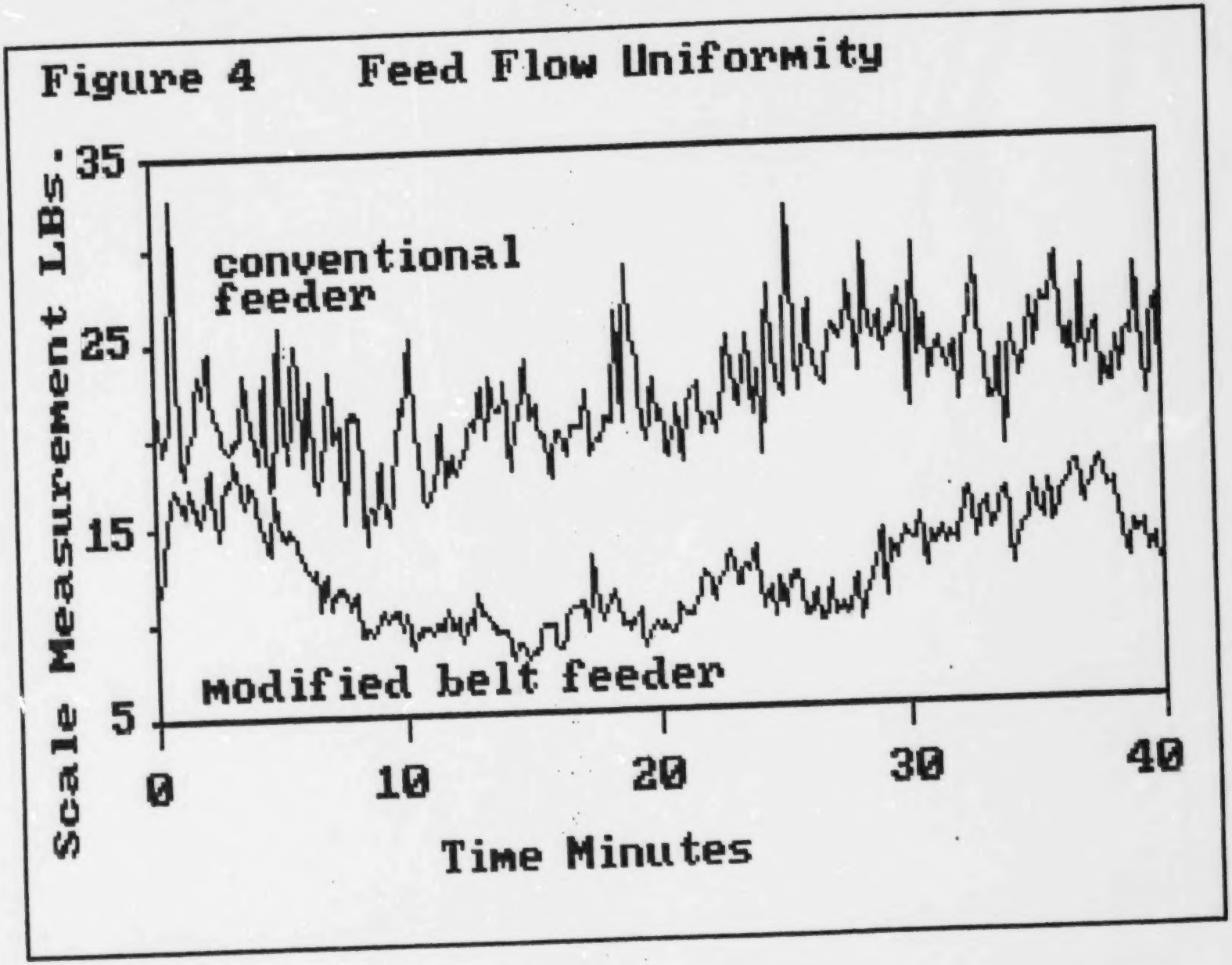


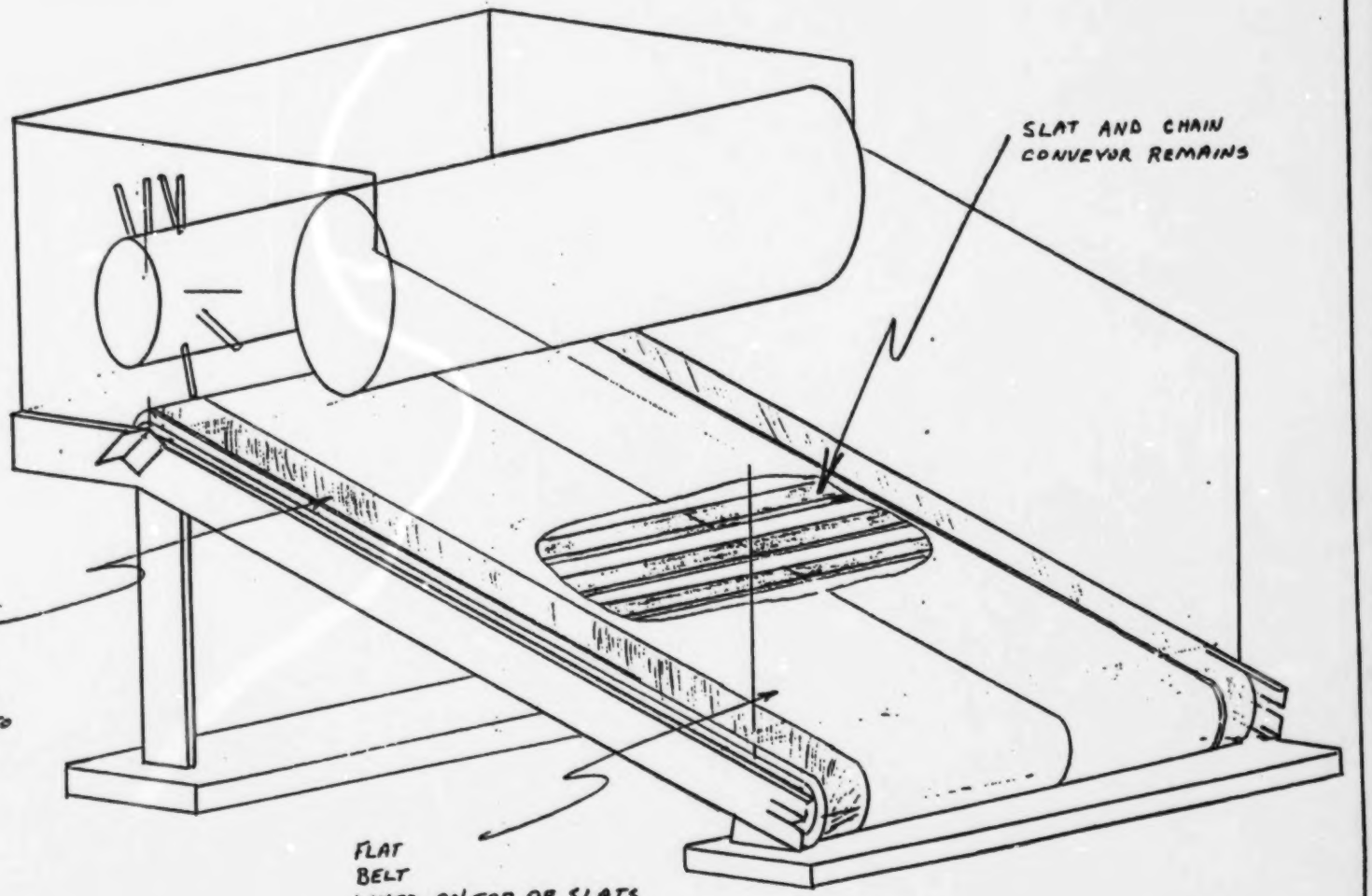
Figure 5 armgif

FIGURE 6: FEEDER CUTAWAY VIEW

MODIFIED FEEDER DESIGN NO. 2

SLAT AND CHAIN CONVEYOR

WITH BELT SURFACE


SLAT AND CHAIN CONVEYOR REMAINS
1/2" RUBBER BELTING ATTACHED TO MAIN BELT COVERS CHAIN.
FLAT BELT LAYED ON TOP OF SLATS NOT ATTACHED

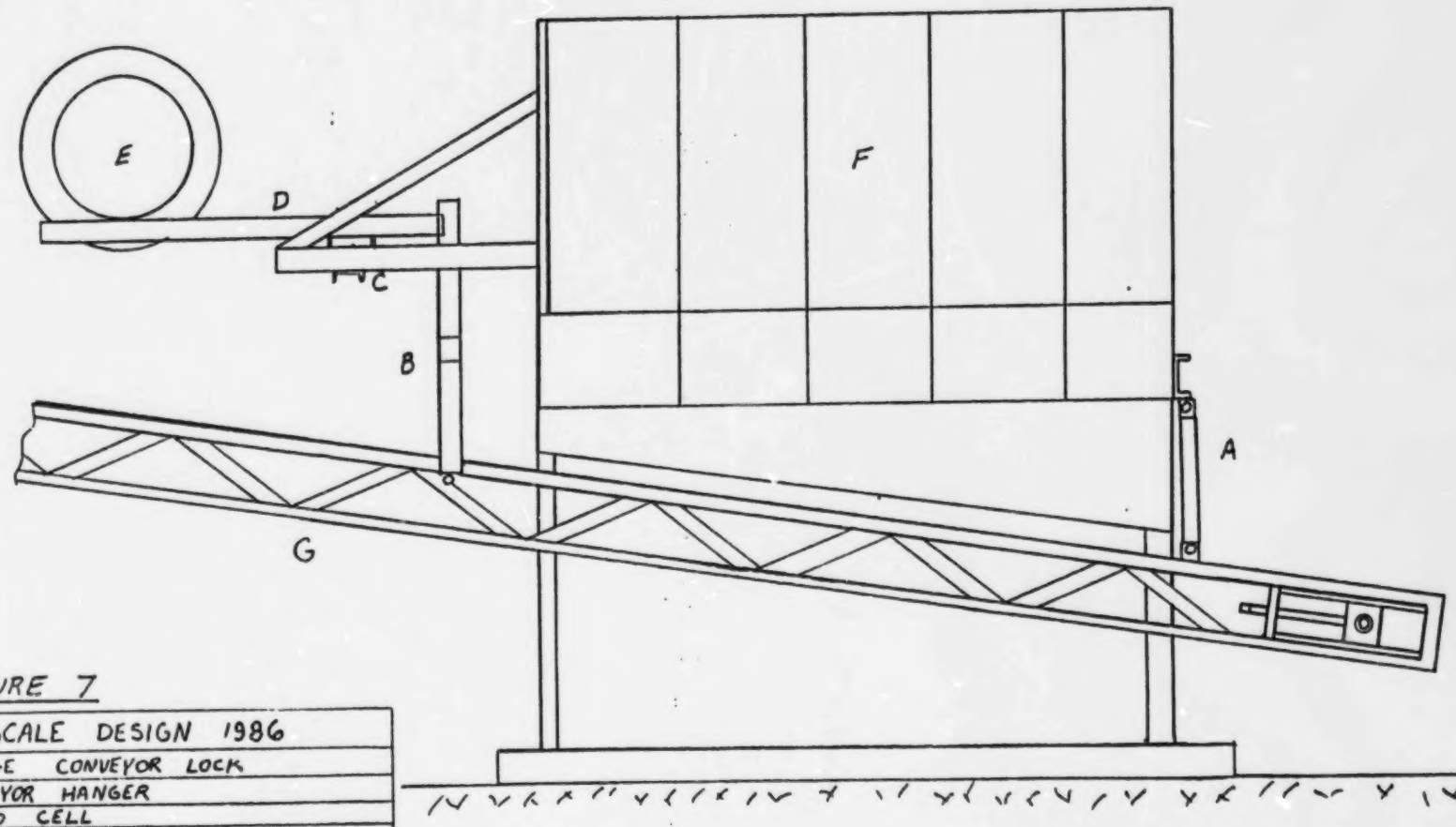


FIGURE 7

BELT SCALE DESIGN 1986
A. HINGE CONVEYOR LOCK
B. CONEYOR HANGER
C. LOAD CELL
D. BALANCE BEAM
E COUNTER WEIGHT (DIE)
F. FEEDER BACK VIEW
G. BELT CONVEYOR

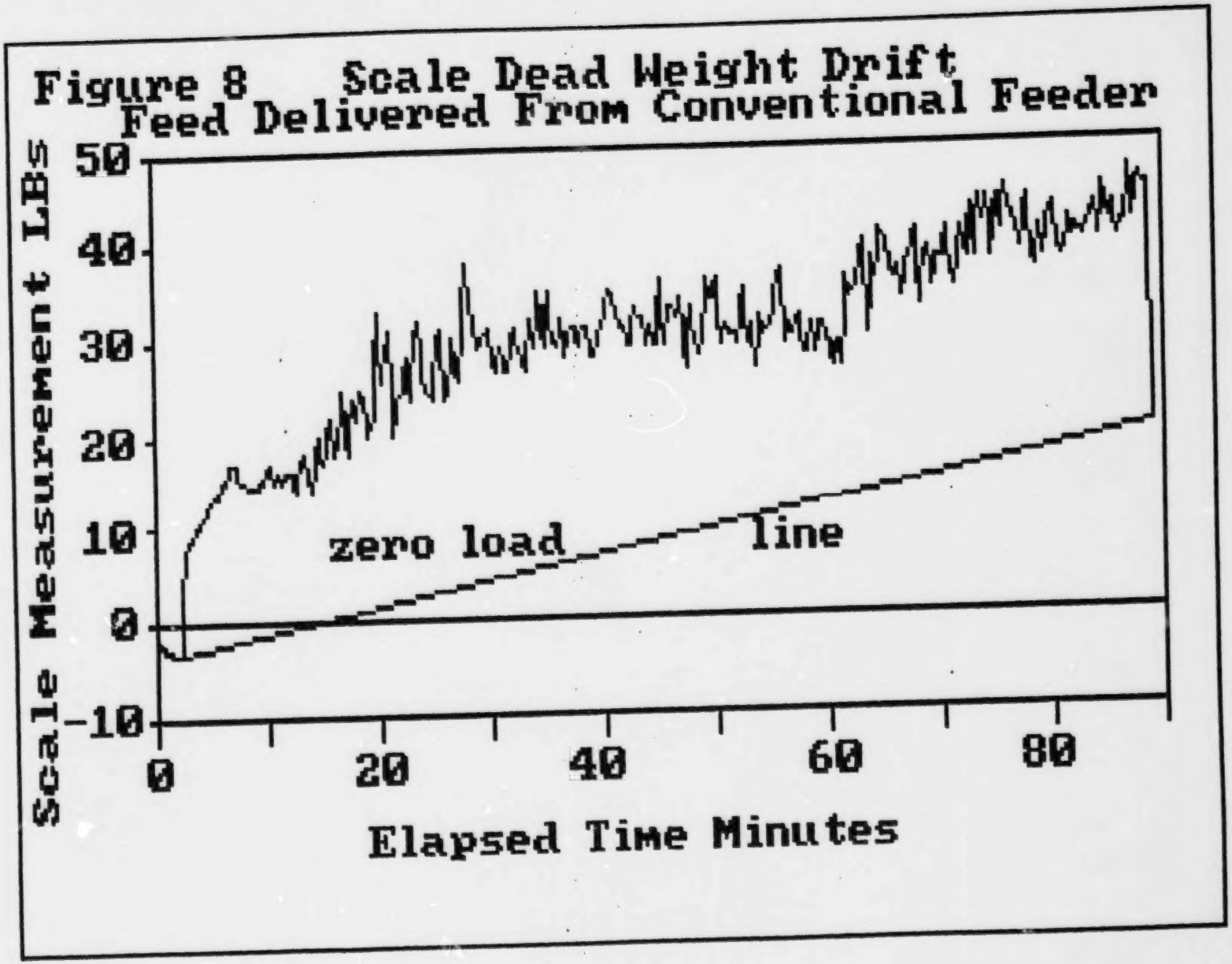


Figure 8 Scale Dead Weight Drift
Feed Delivered From Conventional Feeder
Scale Measurement LBs
50
40
30
20
10
0
-10
zero load line
0
20
40
60
80
Elapsed Time Minutes

Figure 9 Scale Accuracy

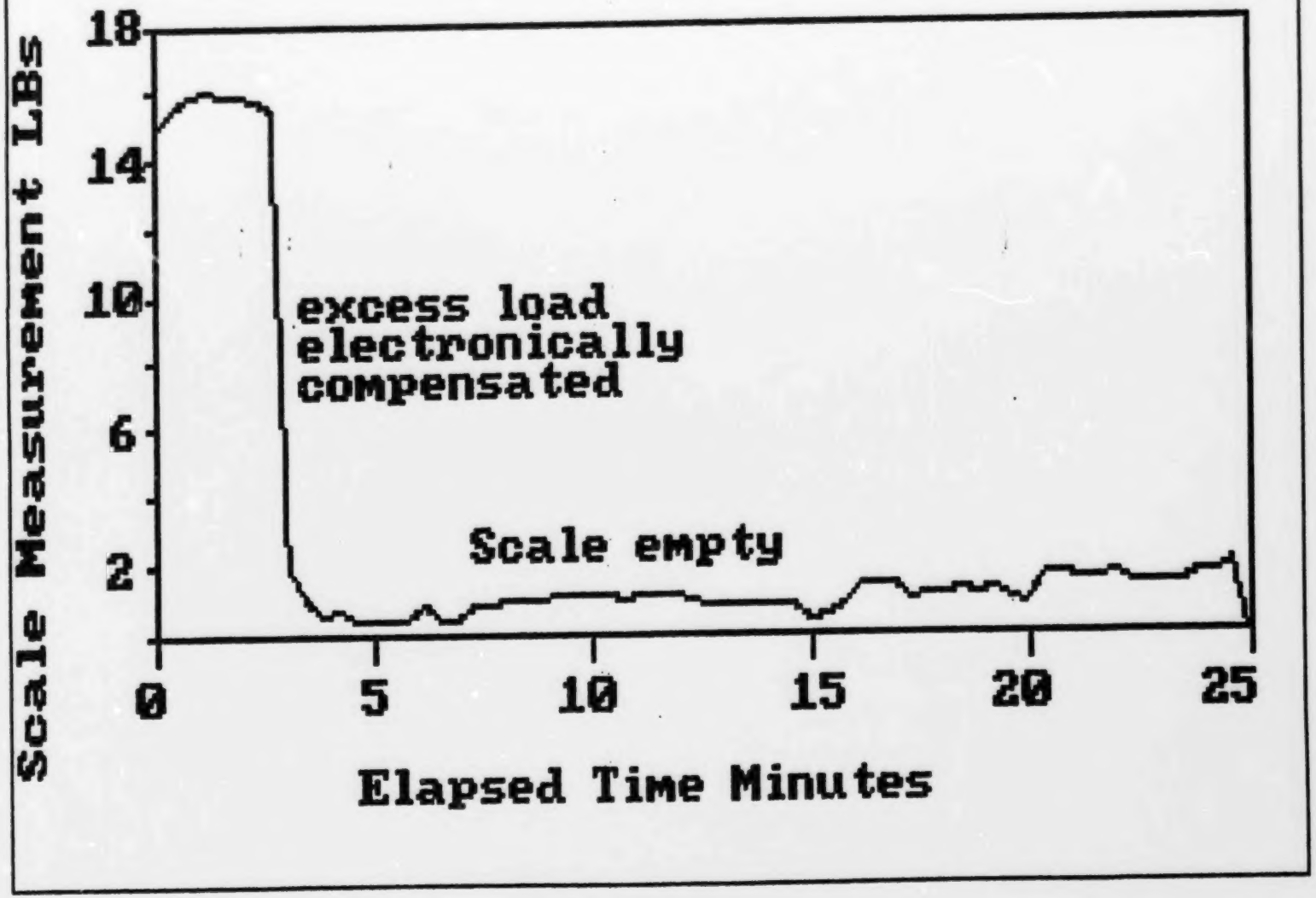
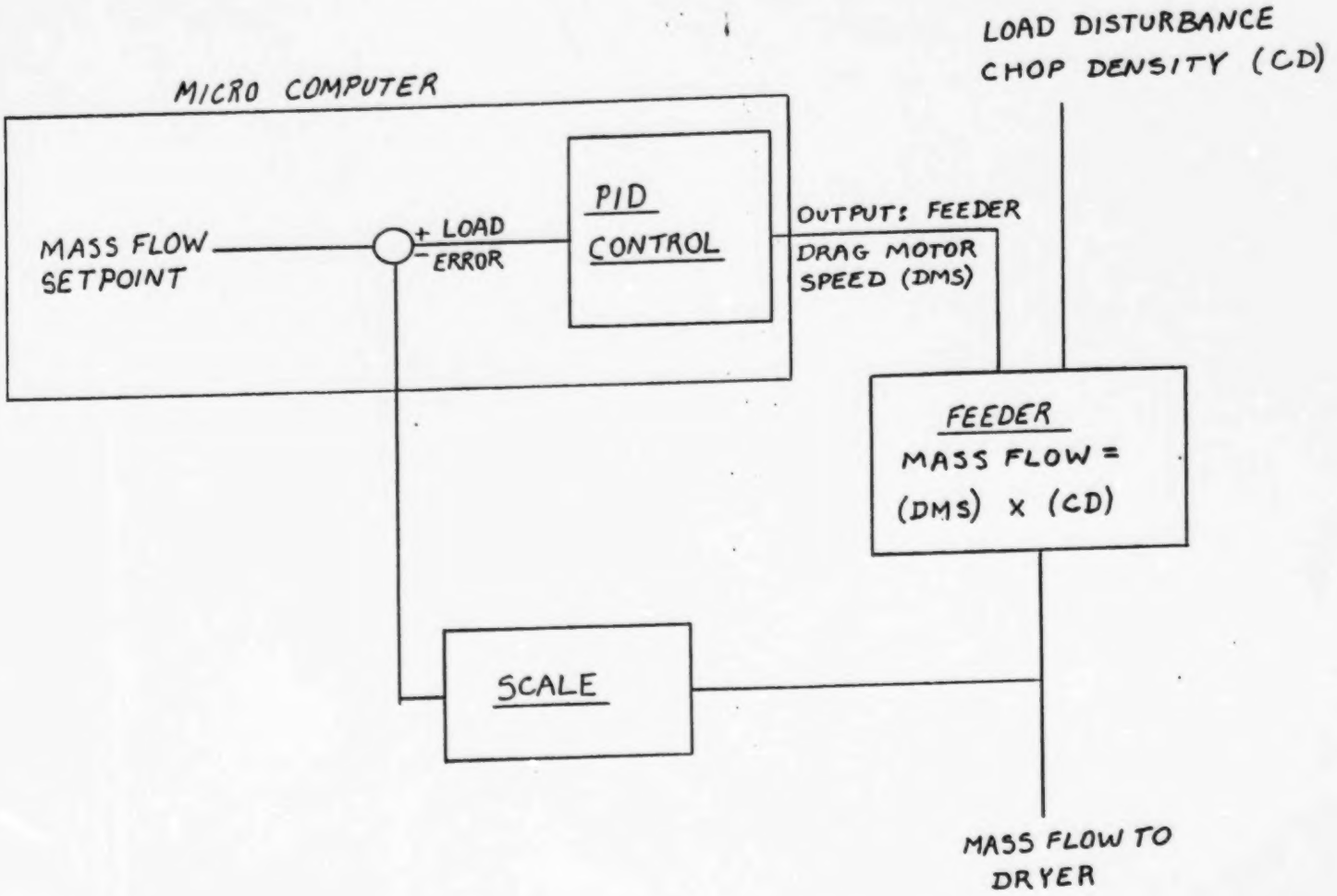


FIGURE 10 : CONTROL SCHEME FOR FEEDER AUTOMATION



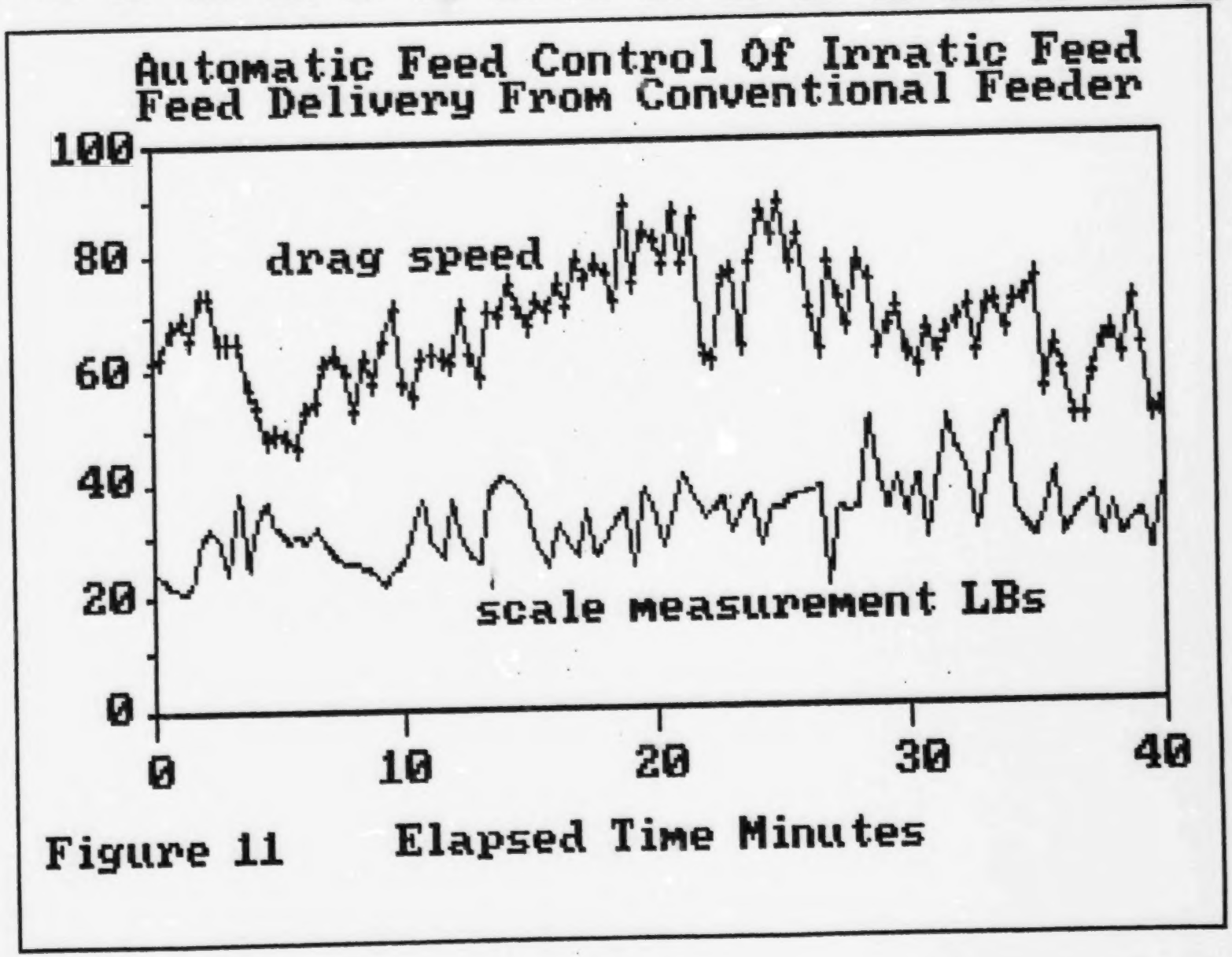

Automatic Feed Control Of Irratic Feed
Feed Delivery From Conventional Feeder
100
80
60
40
20
0
drag speed
scale measurement LBs
0
10
20
30
40
Elapsed Time Minutes

Figure 11

Automatic Control of Feeder Drag Speed
(Final Feeder Design)
100
80
60
40
20
0
0
10
20
30
40
50
60
70
Elapsed Time Minutes
control setpoint 28-30 LBS
scale measurement LBS
controlled
drag speed
drag speed

Figure 12